Senior Thesis

# An Examination of Spring Water Quality Using Crystal Spring, Newark, Ohio

by
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## Abstract

The water quality of springs, contrary to public opinion, is often poor. Springs carry a higher risk of contamination than other groundwater resources. As the need for water increases, springs may be a viable source. However, due to their potential for contamination, springs may be too costly to use as a large scale resource. An example of biological contamination and the cost involved in treating spring water is evident at Crystal Spring in Newark, Ohio. This spring had to be abandoned primarily due to treatment cost.

## Geologic Characteristics and Importance of Springs

Springs are surface water expressions of groundwater. They commonly form where the land surface falls below the height of the water table or where the two intersect. This often occurs along the sides of hills or mountains, along fissures or river beds, and in karst regions (Figure 1). Any discharge of water that can flow in a small rivulet is called a spring (Davis and DeWiest, 1966).

Springs are classified by many types of characteristics. These include the type of aquifer, the chemical characteristics, and the location of the spring (Table 1) (Alfaro and Wallace, 1994). The magnitude of discharge is the most important way in which springs are characterized (Table 2) (Davis and DeWiest, 1966). The quantity of water discharged by a spring is determined by three factors: the quantity of recharge, the area that contributes to the recharge, and the permeability of the aquifer (Davis and DeWiest, 1966). These three factors can be used to determine the geologic and hydrologic characteristics of an area.

The location and magnitude of a spring can help to identify the depth of the water table (Davis and DeWiest, 1966). If a spring occurs on valley sides and hill slopes, it indicates a water table of shallow depth, while a spring located in a valley bottom indicates a deeper water table (Davis and DeWiest, 1966). Springs have been used for a public water source for thousands of years, and are often the sites where groundwater supplies are developed.

## Public Opinion

There is a strong belief in spring purity that prevails in today's society. There are dozens of brands of bottled spring water available on grocery store shelves. Spring water has been bottled for hundreds of years in Europe and became available in the United States at the beginning of the century (George, 1994). The consumption of bottled water in the United States has increased from 488 million gallons in 1979 to two billion gallons in 1991 (LaMoreaux and Powell, 1996). The general public believes spring water to be healthier and cleaner than their local public-water supply. In actuality, spring water usually contains more dissolved solids and is easily contaminated (Davis and DeWiest, 1966). This public opinion concerning spring purity can make it difficult to explain spring contamination to the general public.

A survey compiled in California in 1990, revealed that half of the consumers drank bottled water because of taste, while one fourth stated health reasons and one fourth thought bottled water was free of contaminants (LaMoreaux and Powell, 1996). Another example of public opinion follows with the case study of Crystal Spring in Newark, Ohio.

## Case Study: Crystal Spring, Newark, Ohio

### Regional Geology

#### Bedrock

Licking County is located in central Ohio. This area consists primarily of Mississippian rocks (Figure 2). These rocks are mainly from the Cuyahoga and Logan Formations (Figure 3).

The Cuyahoga Formation overlies the Sunbury Shale, Berea Sandstone, and the Bedford Shale. It contains the Black Hand Sandstone as well as some shale facies (Crombie, 1952). The Black Hand Sandstone is a brown sandstone and conglomerate. The shale facies within the Cuyahoga contain sandstone, shale, and conglomerate in the Toboso facies, and shale and siltstone in the Granville facies (Crombie, 1952). The Cuyahoga Formation is well exposed in the western third of Licking County (Crombie, 1952). This formation is overlain by the Logan Formation, especially in the eastern and central parts of the county (Crombie, 1952). This contact between the two units is usually sharp and distinct.

The Logan Formation contains the Berne, Byer, Allensville, and Vinton members. The Berne member can be seen in eastern and central Licking County (Crombie, 1952). This member is quite thin and easily eroded, but is exposed in valleys that have steep walls (Crombie, 1952). The Berne contains sandstone, conglomerate, siltstone, and shale (Crombie, 1952). This member increases in thickness as you move west through the county, and reaches a thickness of seven feet in Newark Township (Crombie, 1952). The contact between the Berne member and the Byer member is typically sharp.

The Byer member has often been eroded away in many areas of western Licking County, but can still be found along the tops of hills in that area (Crombie, 1952). This member varies in thickness and composition throughout the county, but contains sandstone, siltstone, and shale (Crombie, 1952). This unit underlies the Allensville member.

The Allensville has been eroded in the western portion of the county, but is exposed in southern and eastern Licking County (Crombie, 1952). This member contains siltstone, sandstone, shale, and fine conglomerate (Crombie, 1952). The shale is typically found only in southeastern Licking County, and can reach a maximum thickness of six feet (Crombie, 1952). The Allensville member is overlain by the Vinton member.

The Vinton member is found in eastern and central Licking County (Crombie, 1952). This member has been eroded in many parts of Licking County, but still forms approximately 60% of the exposed bedrock (Crombie, 1952). The erosion has caused this member to be lost in the major river and stream valleys of the county. It contains siltstone, sandstone, and shale, with the sandstone and the shale occurring within the siltstone (Crombie, 1952). The thickness of this unit varies throughout the county due to the erosion that it underwent. In central Ohio, this member is overlain by units that are of Pennsylvanian age.

Rocks of Pennsylvanian age have been eroded away in Licking County. However, a few sparse outcrops can sometimes be found on tops of hills and ridges in the southern parts of Newark, Hanover, and Mary Ann Townships (Crombie, 1952).

### Surficial

The major component of the preglacial topography of central Licking County was a valley, which contained a tributary of the ancient Teays River. This valley was partially filled by Illinoian glacial deposits and then by Wisconsinan glacial deposits (Figure 4).

The Wisconsinan glaciation left many ground and end moraines throughout Licking County, while most of the Illinoian deposits are covered. However, the Illinoian deposits are expressed in the eastern portion of the county. Both episodes of glaciation left a considerable amount of glacial drift deposits, primarily sand and gravel in the valleys, and till deposits on the uplands (Forsyth).

### Soils

There are fourteen soil associations in Licking County (Parkinson et al., 1987). These associations usually contain one or two major soil types. The climate found in Licking County contributes greatly to the type of soil that forms. This climate is classified as humid, temperate continental (Parkinson et al., 1987). However, climate is not the only controlling factor in soil formation. Parent material is the most important factor. In Licking County, the parent material includes glacial till and outwash, stream alluvium, colluvium, loess, and lacustrine deposits (Parkinson et al., 1987).

The glacial till in western Licking County is from the Wisconsinan glaciation and contains large amounts of clay and lime (Parkinson et al., 1987). The Illinoian deposits in eastern and southeastern Licking County are mainly sandstone with very little shale (Parkinson et al., 1987).

Soils that form from colluvium, or underlying bedrock are found in central and eastern portions of Licking County. It has been found that coarse grained sandstone weathers to medium/coarse sand, fine grained sandstone/siltstone weathers to very fine/ fine sand or silt, and shale and limestone will form clay (Parkinson et al., 1987).

## Hydrogeology

During the Tertiary Period, approximately 2 million years ago, the drainage system in Licking County was part of the Teays River. The Teays River drained the east-central United States, including two thirds of Ohio (Hansen, 1987). It flowed in a north-west direction across Ohio that was in a course just south-west of Licking County (Dove, 1960). During this stage of drainage, Licking County was drained by two large rivers. These rivers joined in north-west Fairfield County and then flowed south-west to join the Teays River in Pickaway County (Dove, 1960) (Figure 5). The northern and western sections of Licking County were drained by the western river, called the Groveport River (Stout et al., 1943). Central and eastern Licking County were drained by a Teays tributary called the Cambridge River (Stout et al., 1943). At Newark, the Cambridge River was joined by two tributaries, one south-flowing and one east-flowing. It then flowed into Fairfield County and was joined by several other tributaries before it joined the Teays River (Dove, 1960).

Before the Illinoian glaciation, the drainage pattern of these systems changed, and formed the Deep-Stage Drainage System (Figure 6). The major river during this stage was the Newark River, and it entered Licking County from the Hanover area and followed the route of the old Cambridge River (Dove, 1960). This river was then blocked by the Illinoian glacier, but not before it had deepened its valley to 70-80 feet below the original Teays depth (Dove, 1960). It was the Illinoian glacier that established the current drainage path of the Licking River. The drainage of the Licking River is eastward (Dove, 1960). After the Illinoian glaciation, the majority of the drainage patterns and landscape stayed the same within Licking County. However, there were a few minor changes to the drainage patterns for the North Fork of the

Licking River. All the tributaries to this river were blocked by a "drift" of more recent age (Dove, 1960).

The old Newark River that was filled by the glacial episodes is a good source of groundwater. The glacial sands and gravel throughout Licking County are sources of groundwater.

Presently, the North Fork of the Licking River runs through the western part of the county and through the city of Newark. Newark sits on a plain that is located where the North and the South Fork of the Licking River join (Stout et al., 1943). The Licking River and its many streams drain 780 square miles. The flow is eastward across the county with an average gradient of 3.3 feet per mile (Dove, 1960). The Licking River, it's many tributaries, and the glacial deposits are not the only sources of water available to Licking County residents.

The Black Hand Sandstone, a very important aquifer in Ohio, as well as Licking County, is capable of producing 25 gallons per minute in domestic wells, and is often referred to as the "Big Injun" (Hartzell, 1992). The Berea Sandstone is also located in this area and is capable of producing 5 to 15 gallons per minute (Hartzell, 1992).

## Location of Crystal Spring

Crystal Spring is located in Newark, Ohio, which is approximately 30 miles east of Columbus, Ohio. The spring is at 422 Cedar Run Road, which is located 1.7 miles east of State Route 13 on Waterworks Road (Figure 7). The spring is located on private land owned by Owens-Corning Fiberglas. This area was sold to Owens by Robert Jacks Sr.in 1980. Mr. Jacks is currently a tenant on the property.

The spring is covered by a spring house that was built around the 1700's (Jacks, 1996) (Plate 1). The spring flows into a cement vat found under and at the rear of the spring house (Plate 2). The overflow from this spring flows out approximately three feet from the cement vat, and fills a small cement pond (Plate 3-4). This pond then drains down the front yard of the Jacks' residence (Plate 5). The spring water was piped from the spring house to a pile of rocks alongside the road, where anyone could collect water (Plate 6).

At the present time, all the land in this area is residential. Approximately thirty years ago, this area was pasture land for cattle. This includes the hill that is located behind the spring and at a higher elevation than the spring (Plate 7).

Located approximately one mile north of the spring on Griffith Road, is the Owens-Corning landfill (Plate 8-10). This landfill is where Owens disposes of their waste and is monitored heavily by the Ohio EPA (Figure 8).

## Geology of Crystal Spring Location

### Bedrock

Crystal Spring is located in an area that contains only Mississippian rocks. These are primarily sandstones and siltstones. A stratigraphic section was measured through an area approximately one mile away from the spring location at an area known as Horns Hill Park (Figure 7). This section was completed in 1952 by Richard Crombie (Figure 9). The area is primarily siltstone with a few layers of sandstone. The section reveals that the upper unit exposed is the Vinton member of the Logan Formation, with all units down to the Cuyahoga revealed (Crombie, 1952). The siltstone facies of the Vinton member is quite thick, approximately 89 feet, and may have been thicker at one time since it is the youngest layer deposited (Crombie, 1952).

## Soils

The soils around Crystal Spring are the Ockley-Stonelick Association (Parkinson et al., 1987). These are well drained soil that formed in glacial outwash and alluvium on flood plains (Parkinson et al., 1987). Also found in the same area are the Alfred-Negley-Parke Association. These are well drained soils that formed in glacial outwash on terraces (Parkinson et al., 1987).

## Hydrogeology

Crystal Spring is located near Cedar Run Creek, which is a tributary of the North Fork of the Licking River. The fill from the Newark River that the city of Newark, as well as Crystal Spring, overlies is 300+ feet thick (Stout et al, 1943).

The spring water flows downgradient to the south through the Jacks' yard, until it reaches the road (Plate 5). The water then follows along the road into a small tributary of the North Fork of the Licking River (Plate 11-12). This tributary is west of Cedar Run, which crosses underneath Cedar Run Road.

Mr. Jacks timed the discharge of the spring several years ago. He claims that the spring was able to fill a one gallon milk jug in less than half a minute. This would give an approximate discharge rate of two gallons/minute. According to Meinzer's Classification, Crystal Spring would have a magnitude of six (Table 2).

## Local History

Crystal Spring is the original name of the spring; however, current residents refer to it as Cedar Run Spring due to it's location. The spring has been used as a source of water for hundreds of years. A reference to this spring can be found in the *History of Licking County*. It was considered one of the largest springs in the area (Hill, 1881). However, it was not the only spring of considerable importance.

There was a spring in Newton Township that created a volume of water that could propel the machinery for a grist and saw mill for several years (Hill, 1881). There were also several springs located in Granville Township. All of the springs that were mentioned were non-mineral springs (Hill, 1881). The majority of springs in the Licking County area have been disturbed by development. Crystal Spring was the one remaining spring that continued to be used by the public for water.

## Present Status of Crystal Spring

Newark residents and residents from other counties and states came to Crystal Spring to get fresh, pure spring water. Many of the Newark residents have been drinking water from this spring for dozens of years. The spring was easily accessible alongside Cedar Run Road (Plate 6). Patrons filled milk jugs and other homemade containers with the spring water for immediate use and for storage purposes. For many years, a small grocery store that was located on Front Street in Newark sold the spring water to local residents (Jacks, 1996).

Mr. Jacks, the owner of the spring from 1964 to 1980, made an attempt to sell and distribute the spring water. Approximately ten years ago, Mr. Jacks had the water tested for bacteria, chemical contamination, and important minerals. The test results showed that the water contained no harmful chemicals and was rich in minerals. Mr. Jacks then built a cement drinking fountain across the road from the spring and was planning to pipe the spring water to it (Plate 13). However, Mr. Jacks was not sure that the spring water would be a good investment at the time and sold the land. After selling the land to Owens, Mr. Jacks continued to test the spring water.

Recently, he took three samples to Logan, Ohio for testing. These samples labeled, Well 1, Well 2, and Well 3, were taken from the end of the supply pipe. Two samples came back fine, and one had a high coliform count. According to Mr. Jacks, when the Licking County Health Department took a sample, they did not take it from the supply pipe or the spring orifice. Instead, they took a sample from the rivulet of water that drains through his front yard. This sample came back with a high coliform count. All of these tests occurred several years ago, but residents in the area periodically got the water tested. A gentleman that had major health problems took the water to the Cleveland Health Clinic for testing. The doctors there believed the spring water to be better for him than the water from the municipal supply (Jacks, 1996).

In 1994, the water was again tested by the local health department. According to Caroline o'Neill of the Ohio EPA, a high amount of coliform bacteria was found in the water. However, there are no water test results available from the EPA or the local health department. Also, the water was not tested for chemical contaminants, such as nitrates, that could have been present from the past farmland. Due to public safety requirements, the Ohio Environmental Protection Agency advised that the spring be purified by the owner or shut down. This raised concern among the Newark residents.

The following are several excerpts from *Letters to the Editor* that appeared in the Newark Advocate from February 14, 1994 to February 25, 1994.

> The spring *"was pure in the 1800's and it is still naturally safe to drink"*, Catherine Wade.

*"I feel that the water is God's gift. Let me choose to drink or not to drink."* Mary Ellen Greenwood.

The majority of the residents held the same belief in the spring's purity. The Ohio EPA had a slightly different opinion.

Ohio EPA Ruling

The EPA defines a spring as a public water system that is a surface water source and therefore must meet certain requirements and maintain a certain water quality (O'Neill, 1996). The Ohio EPA gave Owens-Corning five options concerning the spring.

(1) Install a filtration and disinfecting system at the site.

(2) Abandon the spring and install an approved groundwater source.

(3) Abandon the site and install a certain type of approved water system.

(4) Abandon the spring and purchase water from an approved source.

(5) Abandon the spring.

Owens-Corning did not want to become involved in the water business and found that the liability and filtration costs associated with the spring were quite high. They decided to abandon the site, and the supply pipe was removed May 31, 1994 (O'Neill, 1996). This decision did not affect the Newark residents beliefs in the spring's purity.

There is no information about public opinion once the spring was closed down. However, when talking to area residents that used the spring, it is obvious that they are bitter over the decision. They do not hold Owens Corning at fault though. Several people have disregarded the EPA's warning and continue to obtain water at the site. Since the supply pipe is no longer available, they bring buckets and dip the water from the rivulet in the Jacks' front yard (Plate 5). People using this method believe that the water is as pure as when it comes from the spring orifice. This is obviously not the case since the rivulet is not covered and allows all rain water and debris to become trapped in the water.

The closure of the spring did not leave anyone without water. Newark City water is available in the Cedar Run area, although several residents have their own wells. These wells were usually dug before the city water supply was available.

## Springs as a Public Water Source

For a spring to be viable as a large public water source, it must have a high magnitude of discharge. This is the only way in which the cost of developing the spring would be considered cost effective. The Food and Drug Administration (FDA) has proposed several rules under which spring water could be developed (Shehan and Zukin, 1993).

The FDA maintains that the spring water should be collected at the spring itself or at an adjacent borehole (Shehan and

Zukin, 1993). Proper development is needed in order to avoid contamination, and the borehole method would help prevent contamination from surface sources (Shehan and Zukin, 1993).

The National Spring Water Association released the following position on bottled water, "What doesn't flow naturally isn't a spring" (LaMoreaux and Powell, 1996). They point out that many bottled waters that are called spring water actually come from wells. This raises the question, "Can wells intercepting water from the same source as the spring discharge be classified as spring water?" (LaMoreaux and Powell, 1996). This also calls into question the way in which bottled waters are labeled. New laws regulating labels may soon be enacted.

## Spring Contamination

Springs can be easily contaminated by bacteria. The water when obtained at the source often contains a high microbial population (Shehan and Zukin, 1993). Runoff that is contaminated or areas that are used for sewers, livestock, septic tanks, and cesspools when located on higher adjacent land, will often lead to spring contamination (Shehan and Zukin, 1993). Springs can also be contaminated by chemical constituents.

Nitrates, phosphates, and other production chemicals can be found in spring water if the site is located near farmland or a previously contaminated site.

There are two federal laws that concern contaminants in drinking water: the Safe Drinking Water Act (SDWA) and the

Federal Food, Drug and Cosmetic Act (FFDCA) (LaMoreaux and Powell, 1996). The EPA is given jurisdiction over drinking water for public water systems by the SDWA (LaMoreaux and Powell, 1996). The FFDCA gave control of bottled drinking water to the Food and Drug Administration (LaMoreaux and Powell, 1996). Federal laws are not the only regulations that apply to drinking water.

Many states have their own regulations. By January 1993, there were 44 states that had regulations concerning bottled drinking water (LaMoreaux and Powell, 1996).

## Conclusion

Springs have been an important part of society for thousands of years. Today, they still retain their prestigious position of being considered a pure source of water. The public's opinion of spring water will allow the use of springs as a large scale water source to be much easier. However, since a spring is tied to an aquifer, a contaminated aquifer will lead to a contaminated spring. If this is the case, it is often very costly to reclaim a spring, or look at a spring as a potable source of water from a contaminated aquifer.

If the cost of treatment had been low, Owens may have chosen to treat the water and allow the public to retain access. However, since no one was dependent on the spring as their only source of water, the treatment was not an economical solution.

Springs can be an important source of water in the future for large populated areas, but only if groundwater as a natural resource is protected from chemical contamination and the cost for treating bacterial contamination decreases.

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# Appendix

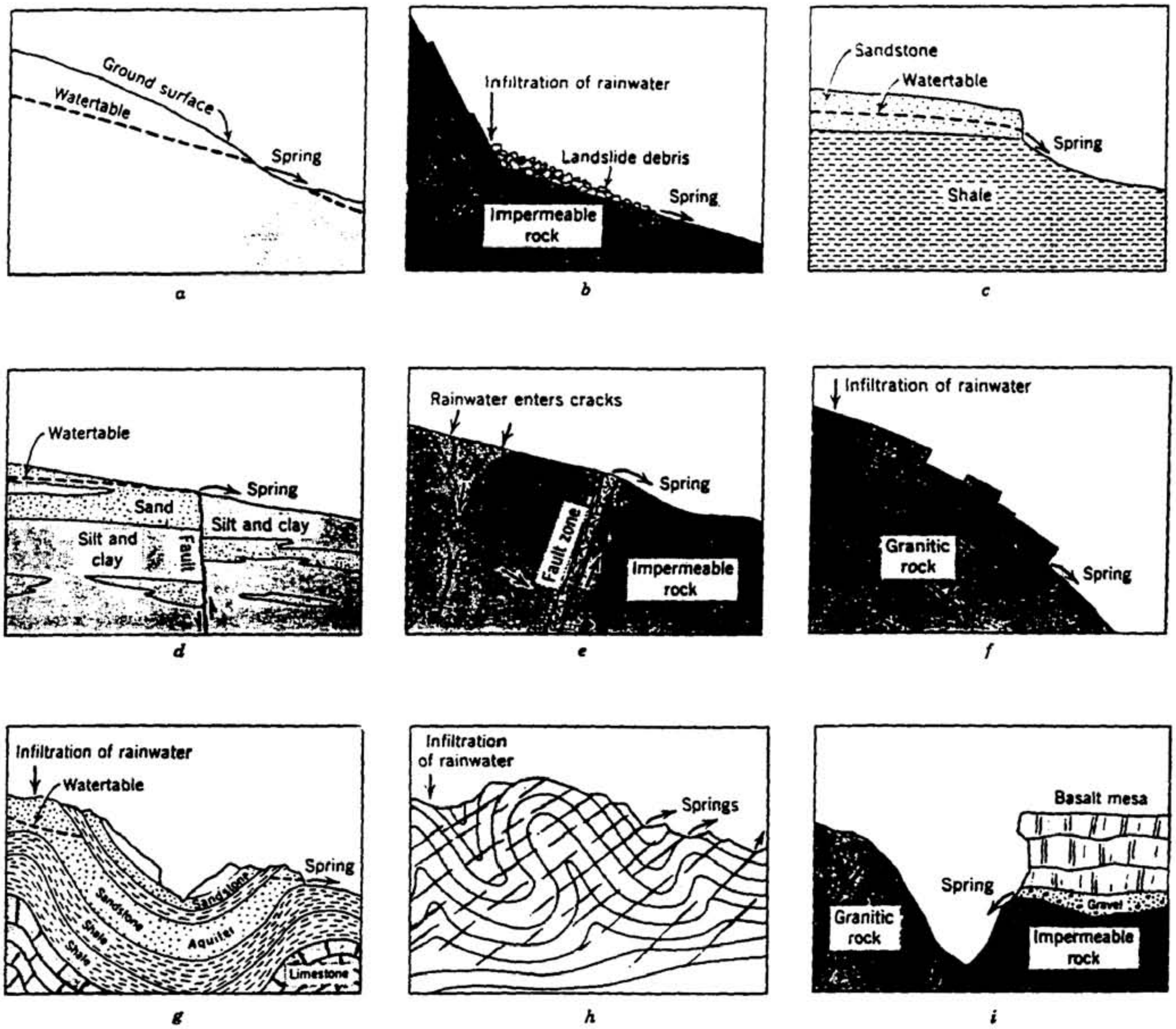
The following are two laboratories where water samples can be taken to be tested for various types of contamination. All laboratories require their own sample bottles be used for sample collection.

| Laboratory | Testing | Area |
|---|---|---|
| Medical Laboratory Specialists | Coliform | Newark |
| Ohio Department of Health | Organic<br>Inorganic<br>Bacterial | Columbus |

The Ohio Environmental Protection Agency located in Columbus, Ohio has a listing of all labs with the ability to test water for any type of contaminants.

When testing for biological contaminants some labs are only equipped to determine a positive result for coliform and are unable to provide a coliform count.

Figure 1 (Davis and DeWiest, 1966)




Springs localized by (*a*) a surface depression that intersects the watertable, (*b*) infiltration of rain water into coarse and permeable landslide rubble, (*c*) permeable sandstone overlying impermeable shale, (*d*) a fault that offsets impermeable beds against permeable beds in alluvium, (*e*) a fault that forms an open fractured zone in brittle rock, (*f*) sheet structure in granitic rock, (*g*) outcrop of an artesian aquifer, (*h*) dominant jointing in one direction, and (*i*) outcrop of permeable gravel and basalt overlying impermeable granitic rock.

**Table 1** Key to the classification of springs

I. Springs due to deep-seated waters, juvenile and connate, admixed with deeper meteoric water; do not flow under hydrostatic head and are usually not subject to seasonal fluctuation.
  A. Volcanic Springs. Associated with volcanism or volcanic rocks; water commonly hot, highly mineralized and containing gases. Grade from gas vents into springs of normal temperature indistinguishable from those due to other causes.
  B. Fissure Springs. Due to fractures extending into deeper parts of the crust; water usually highly mineralized and commonly warm or hot.
    1. Fault Springs. Associated with recent faults of great magnitude.
    2. Fissure Springs. No direct structural evidence as to origin, but because of temperature and steady flow believed to have deep origin.

II. Springs due to meteoric and occasionally other waters moving as ground water under hydrostatic head; many fluctuate in flow with the rainfall.
  A. Depression Springs. Due to land surface cutting water table in porous rocks.
    1. Dimple Springs. Due to depressions in hillsides.
    2. Valley Springs. Due to abrupt change in slope at edge of flood plain.
    3. Channel Springs. Due to depressions in flood plains or alluvial plains caused by channel cutting of stream.
    4. Border Springs. Due to change in slope at border between alluvial plains and playas, lake beds, or river bottoms; relative imperviousness of central clay deposits assists flow.
  B. Contact Springs. Due to porous rock overlying impervious rock.
    1. Impervious rock has a horizontal and regular surface.
      a) Underlying bed is of large extent; common in consolidated sedimentary rock.
        (1) Gravity Springs. Overlying material is soft.
        (2) Mesa Springs. The overlying material is hard, usually sandstone or lava flow; water contained in pores and joints of the rock.
      b) Underlying bed is of small extent; common in unconsolidated alluvium; impervious bed is usually clay, cemented gravel, "mortar bed," caliche, or hardpan.
        (1) Hardpan Springs.
    2. Impervious bed has an inclined and regular surface; all springs on the low side unless the overlying bed is very thick and the dip low.
      a) Underlying bed is of large extent.
        (1) Inclined Gravity Springs. The overlying material is soft.
        (2) Cuesta Springs. The overlying material is hard; of same character as mesa springs.
      b) Underlying bed is of small extent; as in hardpan springs.
        (1) Impervious layer dips away from hill; spring possible.
        (2) Impervious layer dips into hill; spring possible only in ravines.
    3. Impervious bed has irregular surface.
      a) Overlying porous material is thick and of wide extent, contact is unconformity. Gravity, inclined gravity, mesa, and cuesta springs may occur, but springs will be sharply localized at lowest parts of contact.
      b) Pocket Springs. Overlying porous material is unconsolidated and more or less discontinuous, residual soil, talus, landslide debris, alluvium, till, stratified drift, wind-blown sand, or volcanic ash.
      c) Overflow Springs. Irregular floor is not continuous, but porous bed is saturated and overflows at lateral contacts; common at receiving end of artesian systems.
      d) Rock Dam Springs. Irregularities of the rock floor under an alluvial plain force water to surface; these may be projections of floor of basin, projections of partly consolidated older alluvium, igneous dikes, or volcanic plugs.
      e) Fault Dam Springs. Dam caused by faulting.
  C. Artesian Springs. Due to pervious bed between impervious materials.
    1. Dip Artesian Springs. More or less regularly bedded rocks; tilted porous bed crops out in valley; usually sedimentary, also alternations of lava flows, flow breccias, tuffs, gravels.
    2. Siphon Artesian Springs. Similar rocks; folded and with outcrops in valley.
    3. Unbedded Artesian Springs. Rocks not regularly bedded, but mass of porous material is exposed so as to receive water and crops out in valley; occur in till and perhaps in other rocks.
    4. Fracture Artesian Springs. All the conditions above, except that lower end of porous bed does not crop out but an opening allows water to escape. Opening due to fracturing with or without faulting.
  D. Springs in Impervious Rock.
    1. Tubular Springs. Due to more or less rounded channels in impervious rocks
      a) Solution Tubular or Cavern Springs. Due to solution channels in limestones, calcareous sandstones, gypsum, salt.
      b) Lava Tubular Springs. Due to caverns and tunnel in lava flows.
      c) Minor Tubular Springs. Due to channels made by movement of water, decay of tree roots, sand streaks, or shrinkage cracks, usually in unconsolidated sediments.
    2. Fracture Springs. Due to fractures consisting of joints, bedding planes, columnar joints, openings due to cleavage, fissility, schistosity, cross-bedding planes, and faults in impervious sedimentary, igneous, and metamorphic rocks.
      a) Quadrille Fracture Springs. Due to more or less rectangular system of fractures, one of which is parallel to the horizon.
      b) Crosshatch Fracture Springs. Due to more or less rectangular system of fractures, inclined toward the horizon.
      c) Inclined Fracture Springs. Due to inclined fractures, not necessarily systematic.

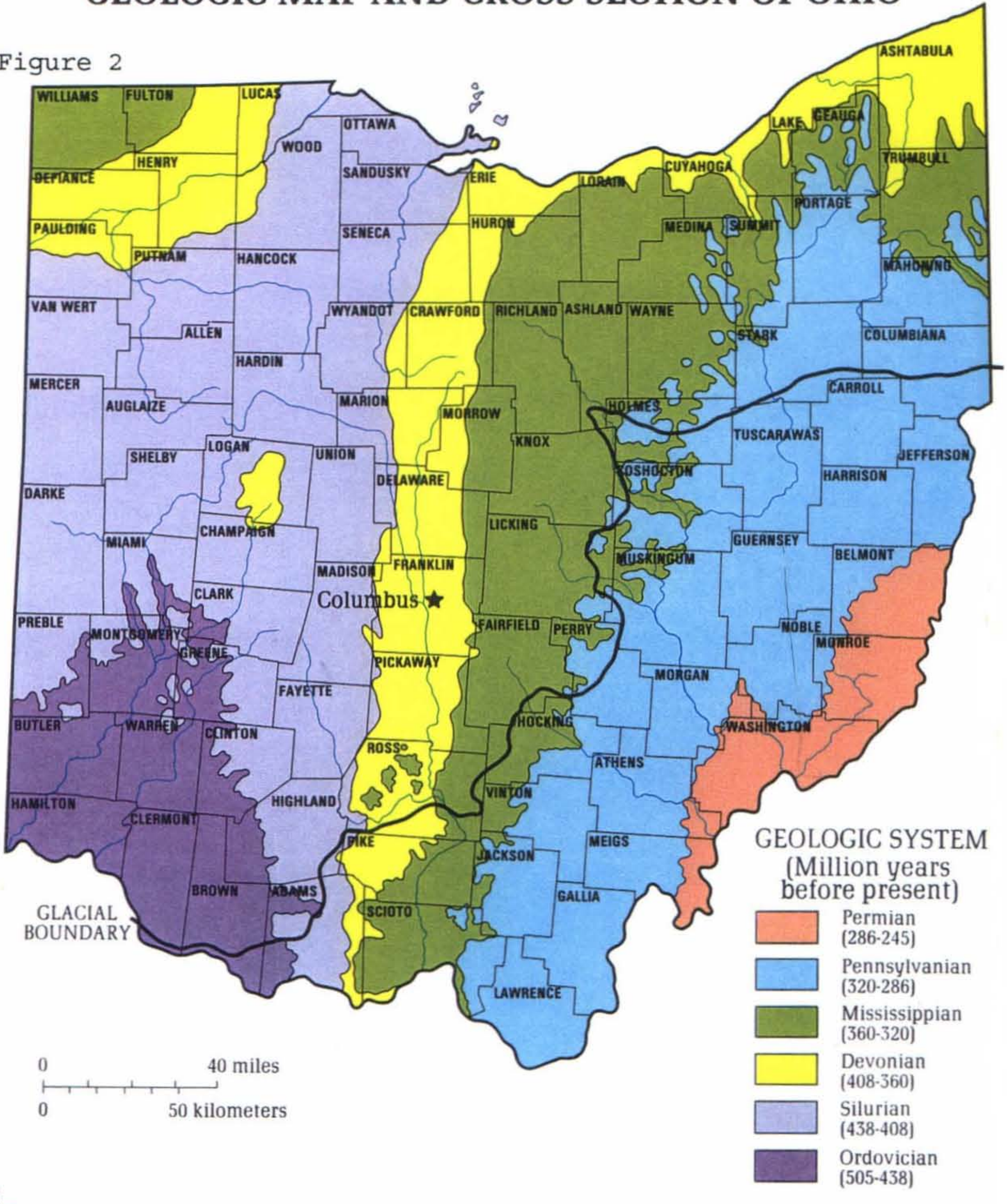
(Davis and DeWiest, 1966)

Table 2 **Meinzer's Classification of Spring Discharge**
(Davis & DeWiest, 1966)

| **Magnitude** | **English Units** | **Metric Units** |
|---|---|---|
| First | >100ft$^3$/sec | >2.83 m$^3$/sec |
| Second | 10-100 ft$^3$/sec | 0.283-2.83 m$^3$/sec |
| Third | 1-10 ft$^3$/sec | 28.3-283 liters/sec |
| Fourth | 100 gal/min-1 ft$^3$/sec | 6.31-28.3 liters/sec |
| Fifth | 10-100 gal/min | 0.631-6.31 liters/sec |
| Sixth | 1-10 gal/min | 63.1-631 ml/sec |
| Seventh | 1 pt/min-1 gal/min | 7.9-63.1 ml/sec |
| Eighth | <1 pt/min | <7.9 ml/sec |

# GEOLOGIC MAP AND CROSS SECTION OF OHIO

Figure 2



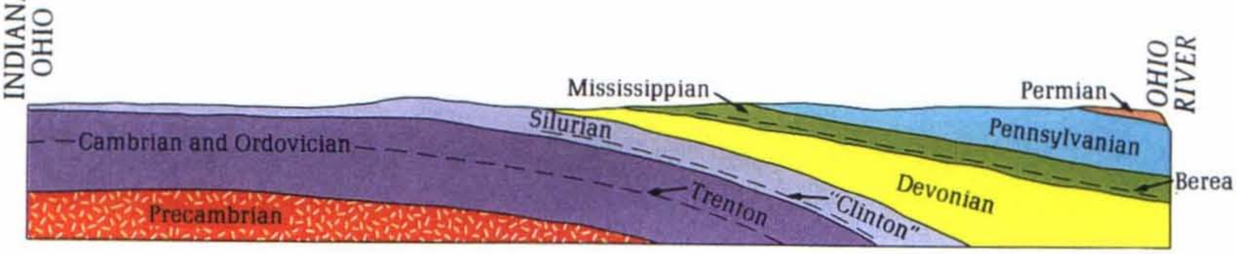
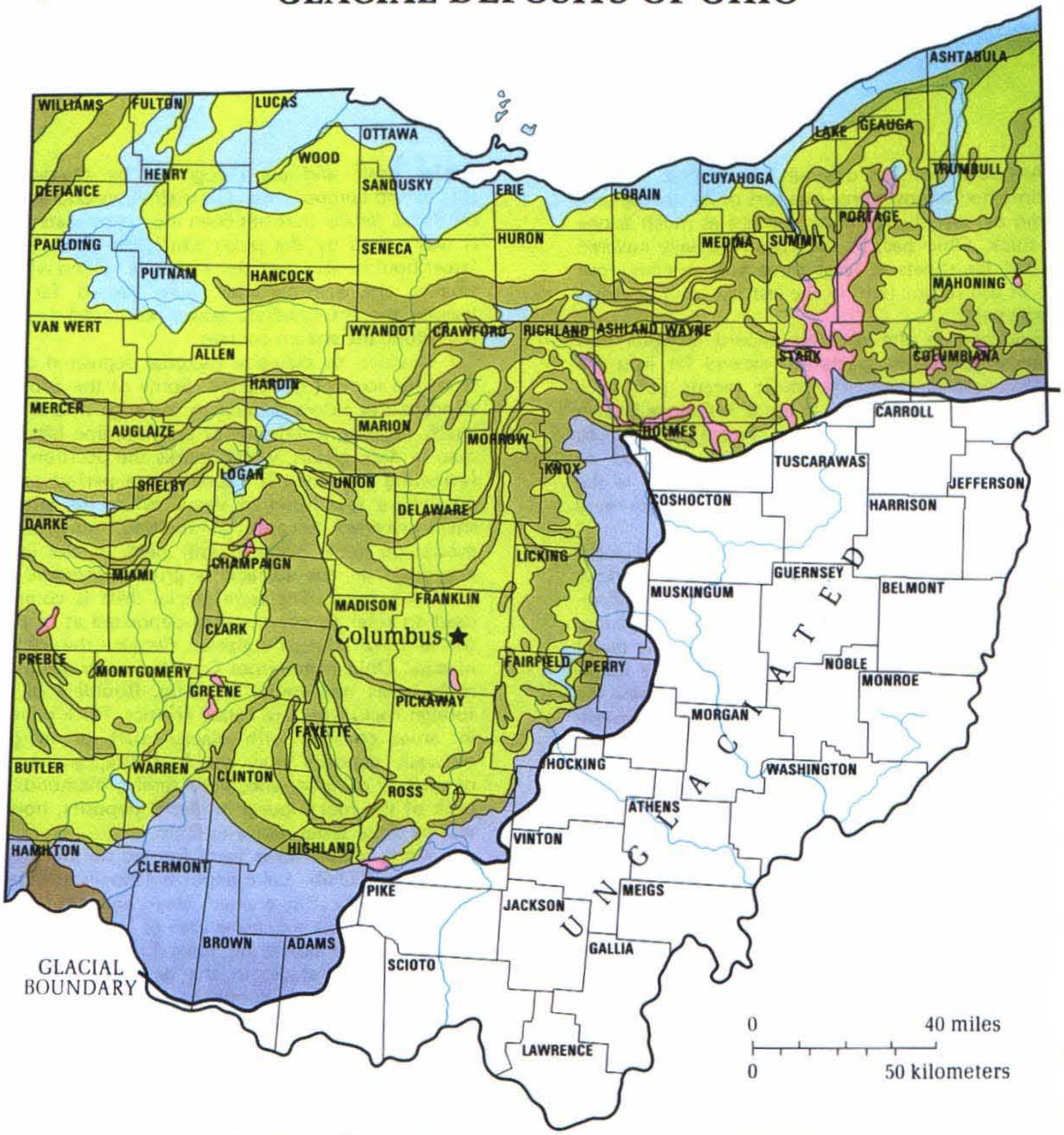



Figure 3 Stratigraphic column of Mississippian rocks of Licking County. (Modified from Graham and Malcuit and Mahard, 1975).

| FORMATION | MEMBER | DOMINANT LITHOLOGY |
|---|---|---|
| MAXVILLE | | Limestone |
| LOGAN | Vinton<br>Allensville<br>Byer<br>Berne | Sandstone, shale<br>Conglomerate, sandstone, shale<br>Sandstone<br>Conglomerate |
| CUYAHOGA | Black Hand | Sandstone, conglomerate |

Figure 4

# GLACIAL DEPOSITS OF OHIO




WISCONSINAN

- Kames and eskers
- Lake deposits
- Ground moraine
- End moraine

ILLINOIAN

- Undifferentiated

KANSAN

- Ground moraine

Figure 5 Teays stage drainage in Licking County, Ohio
(Dove, 1960)

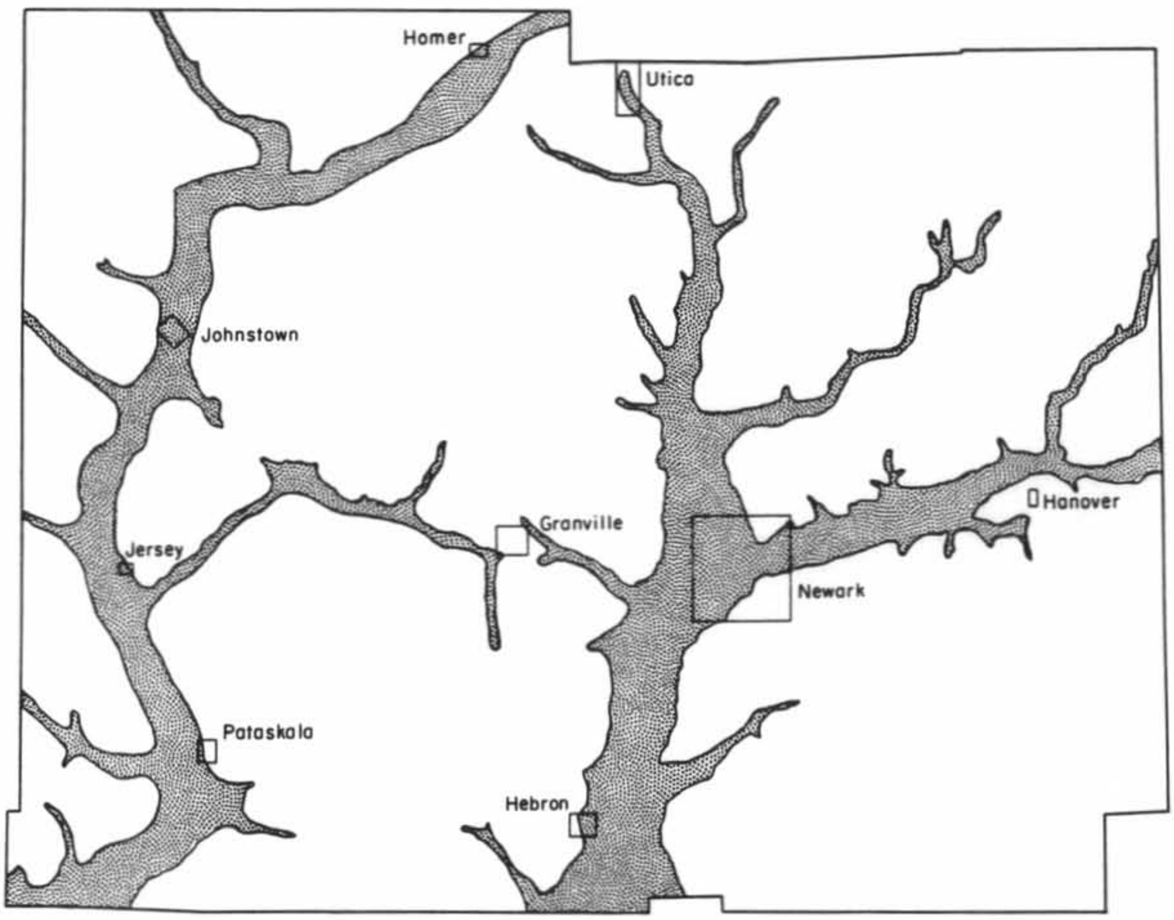
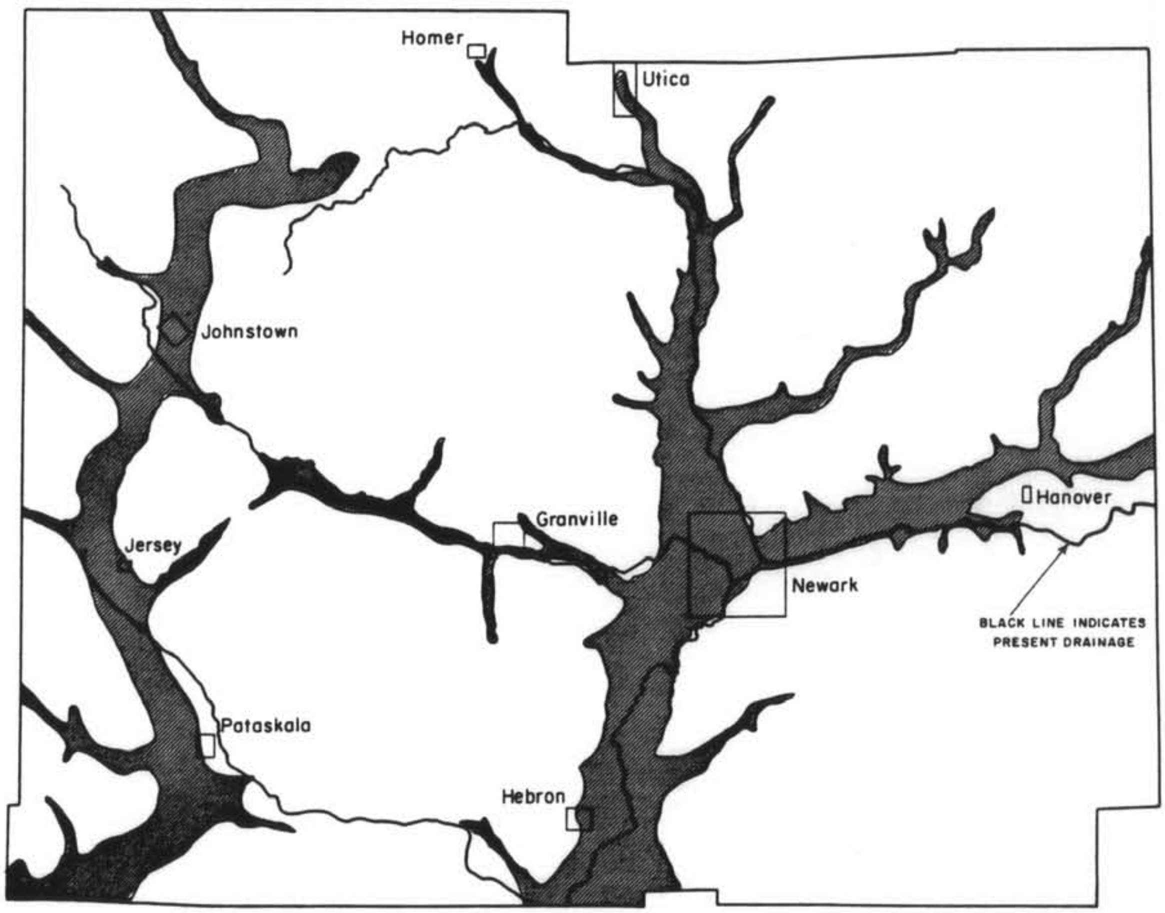


Figure 6 Deep Stage drainage in Licking County, Ohio (Dove, 1960)



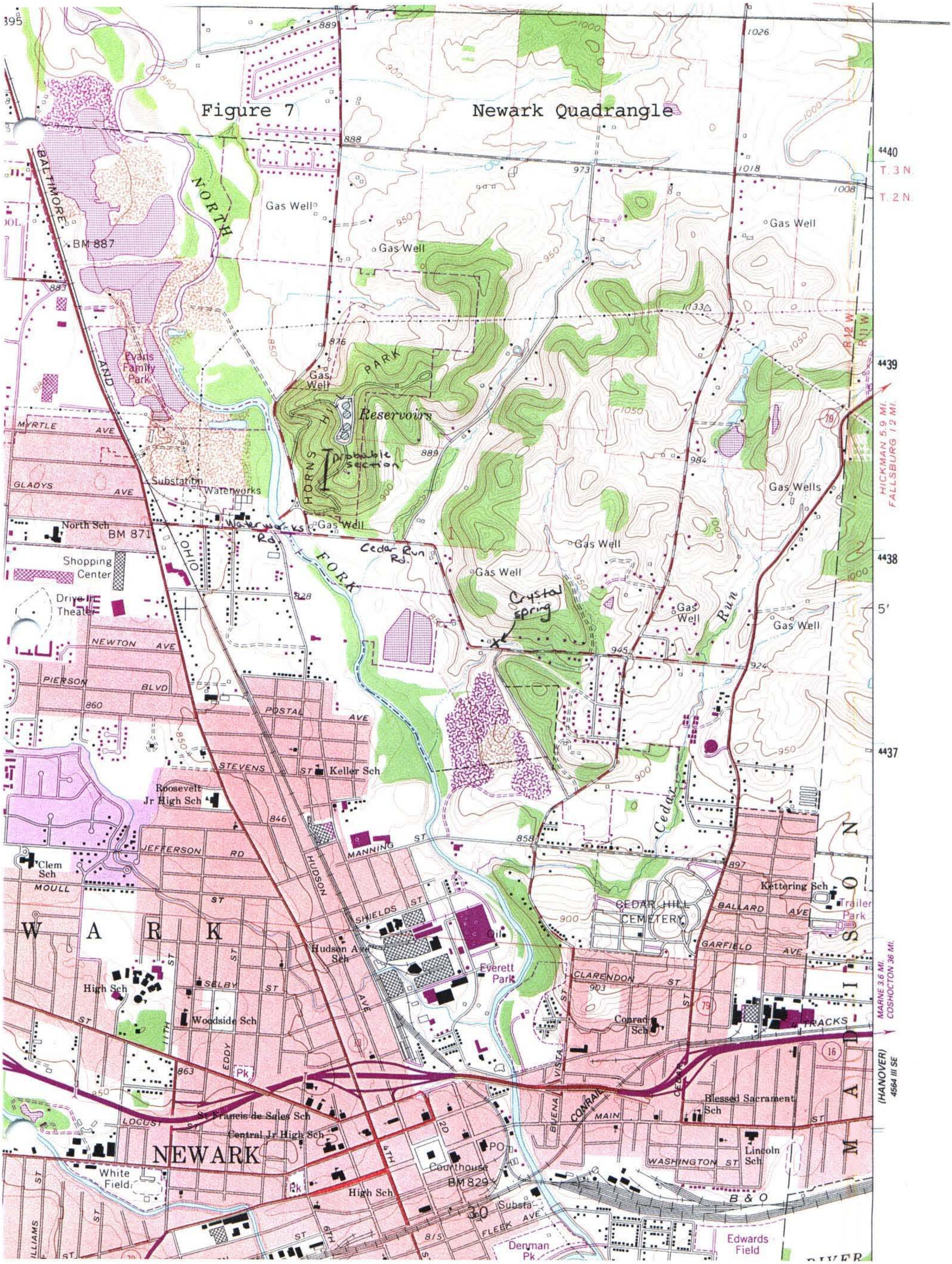


Figure 7
Newark Quadrangle
NORTH FORK
Gas Well
Reservoirs
HORNS HILL PARK
Probable section
Waterworks Rd.
Cedar Run Rd.
Crystal spring
Cedar Run
Evans Family Park
Substation
Waterworks
North Sch
Shopping Center
Drive-In Theater
MYRTLE AVE
GLADYS AVE
NEWTON AVE
PIERSON BLVD
POSTAL AVE
STEVENS ST
Keller Sch
Roosevelt Jr High Sch
JEFFERSON RD
MANNING ST
Clem Sch
MOULL ST
SHIELDS ST
Hudson Ave Sch
High Sch
SELBY ST
Woodside Sch
Everett Park
CEDAR HILL CEMETERY
Kettering Sch
BALLARD AVE
GARFIELD AVE
Trailer Park
CLARENDON ST
Conrad Sch
TRACKS
Blessed Sacrament Sch
MAIN ST
Lincoln Sch
WASHINGTON ST
St Francis de Sales Sch
Central Jr High Sch
NEWARK
White Field
Courthouse
BM 829
Substa
FLEEK AVE
Denman Pk
Edwards Field
B & O
CONRAIL
BALTIMORE AND OHIO
HUDSON AVE
BUENA VISTA ST
CEDAR ST
BM 887
BM 871
T. 3 N.
T. 2 N.
R 12 W.
R 11 W.
HICKMAN 5.9 MI.
FALLSBURG 12 MI.
MARNE 3.6 MI.
COSHOCTON 36 MI.
(HANOVER)
4564 III SE
W A R K
M A D I S O N

Plate 1 Front view of spring house located at 422 Cedar Run Road Newark, Ohio

Crystal Spring appears behind the spring house. The cement overflow pond is in front of the spring house.

Plate 2 Rear of spring house, facing east

This is the covered area in which Crystal Spring flows into a small cement vat.

Plate 3 Overflow outlet of Crystal Spring located behind and to the east of the spring house

The overflow allows the excess spring water to flow into the cement pond in front of the spring house. Mr. Jacks keeps this partially covered to keep animals from entering the spring.

Plate 4 Cement pond located in front of spring house that collects overflow

The tubing that lays alongside the inside of the cement pond was placed there by Mr. Jacks. It helps to direct the overflow into the drainage pipe. The drainage pipe then leads the water through the Jacks' front yard.

Plate 5    Small drainage rivulet located in front of the spring house

The rivulet runs south through the front yard, then turns east and runs into the tributary. The tributary proceeds to the south. Some Newark residents currently attain the spring water by dipping it from this small rivulet.

Plate 6 Rocks located along side of Cedar Run Road, approximately 75 feet from the spring house

The water from the spring house was piped to these rocks. The water flowed out of the end of the pipe, where the public had easy access.

Plate 7 View to the east of the hill located behind the spring house

This hill was used as pasture land for cattle by Mr. Jacks. The barn in the foreground was where he kept his farm equipment.

Plate 8    View of Owens' landfill looking to the north

The landfill is located along Griffith Road and is approximately half a mile away from the Jacks' residence.

Plate 9 View of Owens landfill that has already been partially filled

It has been projected that the landfill can be used for another ten years. The dirt road visible in the foreground is the access road to the landfill.

Plate 10 View of storage building located at Owens landfill

In the background is the industrial section of Newark. The Owens plant is located towards the left edge of the picture.

Figure 8 Enlarged view (200%) of Newark Quadrangle

Middle of NE section of Newark Quadrangle

Figure 9 Measured section through Horns Hill
(Crombie, 1952)

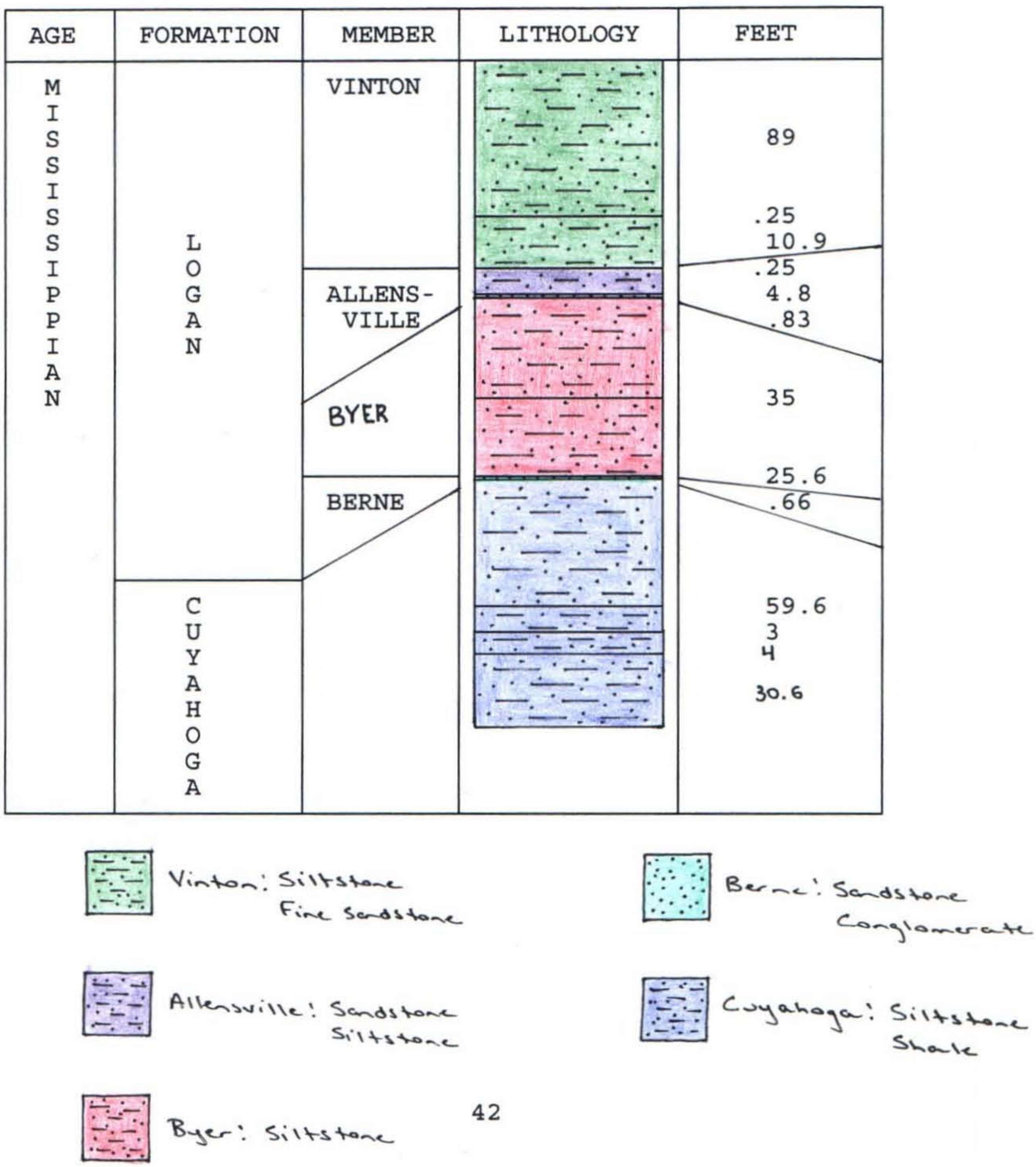


Plate 11    Drainage ditch alongside Cedar Run Road

After flowing through the Jacks' front yard, the spring water flows into this drainage ditch before entering the tributary.

Plate 12 View of tributary flowing to the south

The spring flows south until it reaches the North Fork of the Licking River.

Plate 13 Drinking fountain across the road from the Jacks' residence

The drinking fountain was built by Mr. Jacks when he was going to sell the water. It is located across the road and approximately 150 feet away from the spring house.